Introduction

In 1994, the California Public Utilities Commission (CPUC) initiated a program to investigate various aspects of the debate surrounding a possible link between exposure to electromagnetic fields and health effects. The California Department of Health Services administered this program for the CPUC. One project, the "Power Grid and Land Use Policy Analysis," examined engineering and land use alternatives for reducing exposure to EMFs. The objectives of this project were to provide decision-makers with tools to develop and to assess policies in light of the significant uncertainties about a possible EMF-health relationship.

The project was not expected to make recommendations. Instead it was expected to evaluate the costs and benefits of EMF management alternatives favored by various stakeholders and to determine what degree of confidence that a health hazard exists (if any) would be required to justify remedial actions. For those who wished to challenge the preliminary evaluations, a computer model was developed to allow stakeholders or their experts to modify the assumptions and to explore the consequences of these modifications.

The project and its results are described in a final report (von Winterfeldt et al., 2001a) and an executive summary (von Winterfeldt et al., 2001b). In addition, ten models were developed to assist decision makers and stakeholders to assess and evaluate the impacts of EMF policies. These models were developed with the use of the Analytica software. Both the software and the models are available on the Internet (www.cdhs.ca.gov).

Stakeholders and peer reviewers raised many issues in response to drafts of these documents. In particular, the peer reviewers questioned the practical usefulness of the policy analysis models for decision-making. These reviewers thought that the models were too complex and that the project did not provide sufficient guidance for decision makers and stakeholders on how to use and interpret the models and results.

This guide for decision makers and stakeholders responds to these concerns. First, it compares the decision analysis approach that was used in this project with other policy frameworks. Second, it presents a roadmap on how to interpret and use the models and the results of this project. Third, it presents several simplified models that are easy to use for decision makers and stakeholder who wish to explore the key model assumptions and variables. To accomplish this, the complex Analytica models were simplified to capture only the variables that are important for decision-making. These simplified models were developed in EXCEL and user-friendly interfaces were created to allow decision makers and stakeholders to explore the implications of changing model assumptions and numerical inputs.

This guide was not written as a stand-alone product. It assumes familiarity with the executive summary of the project (von Winterfeldt t al., 2001b) and the following chapters of the final report (von Winterfeldt et al., 2001a):

Chapter 1: Introduction
Chapter 2: The California Power Grid
Chapter 8.1-8.3: Overview of the Analytica Models

In addition, prior to using a specific EXCEL model, readers should familiarize themselves with the corresponding Analytica models described in chapter 8 of the final report. Questions regarding specific calculations of exposures, costs, risks, and other calculations are addressed in chapters 4-7 of the final report.

Policy Analysis in Perspective

Members of the scientific community are far from unanimous as to their degree of confidence that EMFs influence the risk of various diseases. Making policy in the face of uncertainty is characteristic of many public health issues, global warming, mad-cow disease and irradiated foods come readily to mind as examples. In the course of designing and critiquing the power grid policy project, it became clear that stakeholders have different policy frameworks that they use in approaching such problems.

It also became clear that many arguments about policy choices are really arguments about frameworks. Economists, engineers and regulatory agencies often use a predominantly results oriented “utilitarian” framework. Any given stakeholder using this framework considers his/her options along a number of criteria and chooses the option that produces the best trade-offs between the various criteria. In order to find the option with the best balance of criteria, the utilitarian stakeholder may assign dollar values to tangible criteria such as project costs and to other criteria such as aesthetic consequences or human lives saved that do not have a usual market value.

When different stakeholders using this approach end up advocating different courses of action because they have different interests, the utilitarian resolves the conflict by choosing the solution that aims at producing the “most good for the most people at the least cost.” Sometimes this ignores the interests of some small segment of society. On many issues, members of the general public don’t adhere to the utilitarian framework. Often they adhere either to a “social justice” framework that tries to fulfill duties or protect rights of the vulnerable regardless of cost, a “non interference” framework that tries to protect individual and property rights from governmental interference or a framework that requires virtual certainty of a problem before taking action.

Adherents to the different frameworks might prefer different policy options. For example if a municipality that owned its electrical utility decided that magnetic fields from power lines and appliances were hazardous and wanted to do something about it, the utilitarians in town might recommend that the municipal utility should pay for the most cost-effective measures to reduce exposure, As a result, they may advocate reducing EMF exposure from sources other than power lines, for example by replacing old, high exposure electric blankets and VDTs with new, low exposure models to prevent as much disease as possible due to electricity sources.

The adherents to the social justice framework might point out that the minority of people living next to the power grid were still at a higher risk. They might invoke the "precautionary principle" that risk avoidance policies are warranted even if there is uncertainty about whether or not there is a risk. Furthermore, they might argue that policy makers have a special duty to protect the minority of people exposed to the risk if it had been unfairly singled out for EMF or other harmful exposure on the basis of race, or had less access to medical care. From this perspective environmental agents like EMF should be treated as "guilty until proven innocent." Therefore the people living near the lines should be protected by modifying the lines to lower fields even if it was expensive to do so. They might also invoke a duty of the utilities "to clean up their own mess" at their expense.

The adherents to "non interference" might oppose both options because they would involuntarily taxing the many for the benefit of the few. Regardless of the degree of confidence in the existence of an EMF hazard, they might prefer a "right to know" information program to allow the free market and voluntary actions of those who were concerned to solve the problem. Adherents to the "virtual-certainty-required" framework would not want to take any action unless all scientists in the field were convinced of a problem. For them EMFs are "innocent until proven guilty."

There is no technical resolution to these kinds of arguments. A democracy handles them through the political process. However, to address these issues, policy contractors to the California EMF program were instructed to use an approach that would be useful to adherents of all frameworks and to highlight issues where the different policy frameworks might lead to different conclusions. The intention was to assist decision-makers to anticipate how features of different policy options might be attractive to stakeholders who adhered predominantly to one or the other policy framework.

The social justice, the "non-interference" and the "virtual-certainty required" frameworks are governed by fairly straightforward prescriptive principles and they are generally easier for stakeholders to grasp. The results oriented utilitarian analysis by its nature requires extensive discussion of the potential consequences and costs of each option under consideration. Because of this, the policy analyses were primarily addressing the issues raised by utilitarian stakeholders.

In forming policy about the ubiquitous exposures from electricity, policy makers need to decide ahead of time if they will be considering issues of cost and if they would take action based on any degree of confidence about an EMF hazard less than 100%. For those who ignore costs or only act if there is virtual certainty of a hazard substantial parts of the policy projects supported by the California EMF program will not be helpful. For those who do consider these issues, the policy analysis should be helpful.

The decision analytic framework used in this power grid and land use project is consistent with the utilitarian framework, but it also addresses some of the concerns of the social justice, "non-interference", and "virtual certainty required" frameworks. First, rather than assuming that EMF is or is not a hazard, it asked what would be the minimum degree of confidence and the minimum magnitude of risk that would warrant actions. If a protective action is very inexpensive, even a low degree of confidence of a small risk can be justified in a decision analysis. If a protective action is very expensive even complete confidence that EMFs cause a rare disease would not be warranted from a decision analysis point of view. Second, instead of combining all the costs and benefits into a single number, the results are presented separately for each cost or benefit component (e.g., health cost, outage cost, property values benefits, etc.) so that if some costs pertain to one party and other costs to another, this is clearly presented for decision makers whose framework pays attention to the distribution of costs and benefits. Third, the decision analysis framework is presented in a way that allows stakeholders to use their own judgments about the facts and values concerning the costs and benefits of EMF mitigation.

While the decision analysis approach clearly separates the sources of costs and benefits, it does not make recommendations about how the costs and benefits should be allocated to stakeholder groups. For example, it is conceivable that the costs of EMF mitigation are allocated either to utility shareholders, the ratepayers, to residents who might benefit from the mitigation, or any mix of these groups. The analysis does not provide any guidance about the best allocation of costs and benefits. As a result, decision makers will have to rely on ethical and moral principles when making these allocation decisions. We conducted a workshop on ethics and environmental justice as part of this project, and some of the findings of this workshop help (see chapter 10 of the final report).

When conducting decision analyses with multiple stakeholders, disagreements can occur at three levels: decision framing, values or facts. The most fundamental disagreement is about the framing of the decision problem including the definitions of the alternatives and criteria to be considered in the analysis. Our project team spent a considerable amount of time with stakeholders to define a common decision frame (see Chapter 3 of the final report). Stakeholders recommended several scenarios representing EMF mitigation problems, many policy alternatives, and numerous criteria of evaluating policies. In the end, the policy analysis included ten scenarios, between three and nine alternatives for each scenario, and 39 criteria, including 19 EMF criteria and 20 non-EMF criteria. While this made the modeling effort more complex, it also contributed to stakeholder acceptance of the overall decision framework. Incorporating all stakeholder criteria also served the purpose of identifying which if these criteria were important for decision making and which were not.

Stakeholders generally agreed on the framing of the analysis, but they disagreed about the framing of the property values impacts resulting from undergrounding a power line. Decision analysts, like economists take a “forward” look and estimate costs and benefits as future changes from the current situation. When considering the alternative to underground an existing overhead power line, this “forward” look suggests counting property value impacts as a <u>benefit</u> of undergrounding. Stakeholders representing residents living near power lines strongly disagreed and instead wanted to count property value impacts as a <u>cost</u> of existing overhead lines. To accommodate these different frames, the models provide a "toggle" that switches the property value impacts from a benefit of undergrounding to a cost of overhead lines.

Values are typically expressed by statements like "Human health is more important than mitigation cost." Decision analysis captures these value judgments as tradeoffs. In this analysis, we used tradeoffs in the form of equivalent costs for units of several criteria, typically using a wide range to accommodate stakeholder choices. For example, we used an equivalent costs between $0 and $500,000 to value the loss of one life-year and between $0 and $20 to value the loss of one person-hour of electricity. Within this range, each stakeholder can express their own value judgment and thus characterize the relative importance of the criteria.

Factual disputes arise when developing estimates of how a policy alternative performs on a criterion. These factual disputes can focus on assumptions, numerical inputs, or methods of calculation. Our cost estimates for EMF mitigation were by far the most disputed ones. Utility representatives thought that our cost estimated were too low, residents thought that they were too high. As with value judgments, the final models provide the stakeholders with a fair amount of flexibility to adjust the factual estimates. For example, the models let the use change costs from a fraction of our base case estimates to roughly fivefold.

The decision analysis models addressed uncertainties about EMF risks explicitly, by using two variables: The probability that a hazard exists (p) and the degree of seriousness of the hazard, expressed as a risk ratio (RR). Given the choice of p and RR, the models calculate the expected population risk. The stakeholder opinion about these two variables covered a wide range of probability (from zero to one) and of risk ratios (from one to five). In the final analysis, we leave the choice of these values to the decision makers and stakeholders.

The decision analysis models thus define a framework for exploring decision maker and stakeholder preferences among the policy alternatives. They are not suited to find the "correct" decision. Running the models will highlight what variables are important to the decision and which ones are not. The analysis also identifies key points of agreement and disagreement among stakeholders. For individual stakeholders it will show, how sensitive their assumptions about values and facts are to their conclusions.

With so many variables and so many stakeholder inputs and options, can this type of analysis make a contribution to decision making? We believe it can. First of all, one has to recognize that all calculations in this analysis are bounding calculations – with bounds provided either by logic and reason or by stakeholder assessments of values and facts. These bounding calculations produced several findings:

1. Only four criteria were able to change the preferences among the policy alternatives: EMF health effects, cost, property values, and outages.

2. Several assumptions and numerical variables have a strong influence on the model results, including the parameters of the financial model, the probability of a hazard, and the risk ratio.
3. Some policy alternatives were found to be clearly inferior, for example raising the pole height or increasing and existing right-of-way.
4. In each scenario, three alternatives emerged as contenders: No change, moderate engineering change (e.g., rephrasing or reconfiguring lines), and undergrounding.
5. Property values can be a crucial ”swing vote” in determining the preferred alternative among the three contenders.

Insights like these do not make the decision easier, but they create a clearer picture of the choices and the tradeoffs. With these insights, created from running a fairly complex set of models, we were able to create the simplified models that are described in this report. These simplified models make it easy for decision makers and stakeholders to conduct an exploration of their assessment of facts and values within the decision analysis framework. Combined with a deeper understanding of how other stakeholders view this problem, decision makers can gain insights that contribute to better decision-making. However, the models should not be interpreted as providing “objective” results or “correct” answers.

A Roadmap for Using the Policy Analysis Models

The Analytica models developed as part of this project were intended to be user-friendly and allow decision makers and stakeholders to explore the effects of their own judgments about assumptions, facts, and values on the results of the model. However, as the stakeholder and peer reviews indicated, the models and results of the policy analysis were not easy to use. The complexity of the model increased because many scenarios had to be examined to study local power grid conditions and because stakeholders requested to study more criteria at increasing levels of detail. With ten local scenarios, 19 EMF and 20 non-EMF criteria, between three and nine alternatives, and some very complex sub-models, the analyses as presented in the Analytica models was not very transparent.

Given this complexity, stakeholders and decision makers need guidance on how to make some of the key choices that influence the Analytica model results in important ways, including choices of

1. the specific scenario
2. the non-EMF criteria
3. the EMF criteria (health endpoints)
4. the probability of a hazard and the risk ratio
5. the economic assumptions
6. the value tradeoffs
7. the factual numerical inputs regarding mitigation effectiveness, cost, and outages.

These choices are discussed briefly below.

The user can choose among ten local scenarios:

- transmission line retrofitting (three scenarios)
- building new transmission lines (three scenarios)
- distribution line retrofitting (two scenarios)
- retrofitting home grounding systems (two scenarios)

We did not include new distribution line scenarios, since distribution lines are usually placed underground in new developments, thus providing a high degree of reduction of EMF exposure. We also did not include new home grounding scenarios, since new home grounding systems typically produce low EMF exposure.

We also examined the statewide implications of applying the policy alternatives to the whole California power grid system. These were created by using the local scenarios to provide wide ranges of possible costs, health effects, property value and outage impacts. These ranges were then applied to the statewide system to explore low-end and high-end impacts of mitigation measures on the statewide level. Because of the limitations of the local scenarios and the difficulty in generalizing local conditions to statewide conditions, these statewide scenarios have to be interpreted with caution.

Before choosing a scenario, we recommend that stakeholders familiarize themselves with all ten scenarios in chapter 8 of the final report. We also recommend that the stakeholders familiarize themselves with the local scenarios before examining the statewide implications described in chapter 12 of the final report.

As an example, let's assume that a stakeholder is interested in retrofitting a particular stretch of a transmission line in a residential area. In this case, there are three choices: a 69kV line on street side poles, a 115 kV line on a cleared right-of way and a 230 kV line on a cleared right-of-way (chapters 8.3-8.5 of the final report). Other scenarios can be created to fit the stakeholders' interest more closely.

As another example, let's assume that a stakeholder is interested in the statewide cost of undergrounding distribution lines. In this case, the two distribution line models provide guidance about how to generalize the costs and benefits of undergrounding a portion of the distribution system (chapter 12 of the final report).

The Analytica models include 20 EMF and 19 non-EMF criteria. Many of these criteria cannot make a difference to the policy decision, because the impacts of the policy alternative on these criteria are very small. The criteria that can make a difference are EMF health effects, cost, property values and outages.

There are three cost components: Total project cost (TPC – which captures the cost of engineering design, management, and construction), operations and maintenance, and conductor losses. In some cases, the stakeholders may only be interested in total project cost (TPC). Operation and maintenance costs and conductor losses can be high, but they do not differentiate as much between the policy alternatives than TPC. In general, the cost analysis shows that the TPC component differentiates between the "No Change" alternative (zero TPC), the "Moderate Change Alternative" (TPC in the range of a few thousand dollars per mile) and the "Undergrounding" alternative (TPC between $750,000 and $3 million per mile).

Some stakeholders may want to examine the results of the analysis with and without considering property value impacts. Property value impacts depend on the density of properties near a power line, the average property values and the assumed property value increase or decrease. In the scenarios this impact varies between $500,000 and $2,000,000 per mile. In many scenarios, property values are the "swing vote" that can make undergrounding an attractive option, if included.

Outages also contribute to the overall systems cost, but the difference in outage costs between the policy alternatives is not very large. For lower voltage lines overhead configurations tend to have higher outage costs than underground lines. For higher voltage lines, underground configurations tend to have higher outage costs, primarily because of the longer duration of the outages.

Another important choice is which health effects to include in the analysis. The policy analysis explicitly models the following health endpoints:

1. Brain Cancer
2. Leukemia
3. Breast Cancer
4. Alzheimers' Disease

These health endpoints are modeled separately for children and adults. Leukemia, the disease with the most consistent associations with EMF exposure represents about $1/5^{th}$ of the overall health impacts of the four endpoints. Thus, if a stakeholder chooses leukemia as the only health endpoint, the results change to make the "No Change" alternative more attractive and the "Undergrounding" alternative less attractive.

In addition to providing stakeholders with options to select health endpoints, the Analytica models also allow them to define the probability of a hazard p and the risk ratio RR separately for different health endpoints. These estimates are very controversial and it was impossible to obtain agreement on them among the stakeholders. We therefore only defined ranges for these variables and conducted extensive sensitivity analysis to determine which policy alternative would be preferred, given a combination of p and RR. Most of the results in the final report are presented as two-dimensional graphs of p vs. RR which show the regions in which no change would be selected (low p, low RR) vs. moderate action (medium p, medium RR) vs. undergrounding (high p ,high RR). Figure 1 is an example.

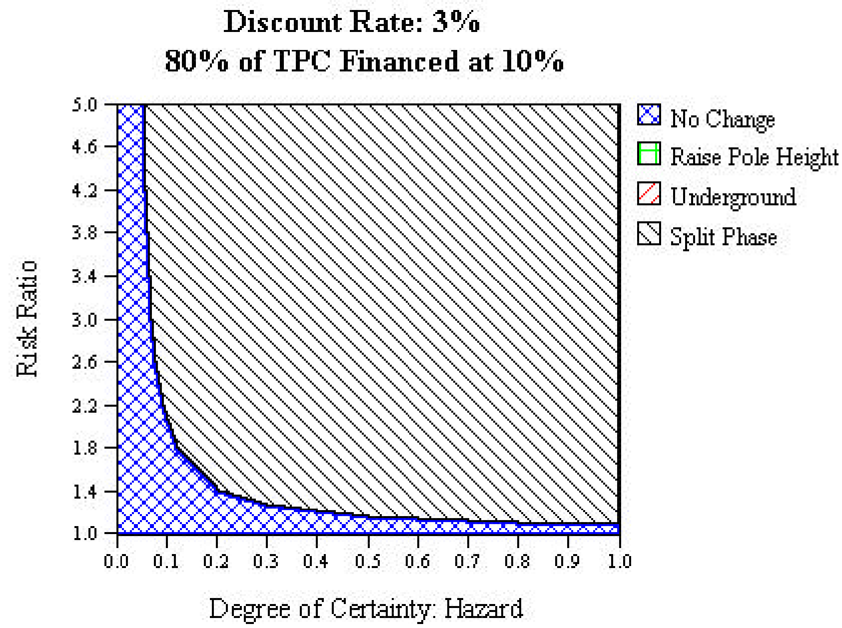


Figure 1: Two-Way Sensitivity Analysis on the Risk Ratio and the Degree of Certainty for 69kV Transmission Line Retrofit
(All Health Endpoints, TPC Financed, Property Values Included)

The stakeholders can also choose specific numerical values of p and RR, and thereby conduct a more detailed analysis of the consequences of this choice. These choices strongly determine the results of the analysis and therefore must be made with much care.

The models provide three choices that represent economic assumptions: the percent of the total project cost that is financed, the interest rate on the financed amount, and the discount rate. These assumptions have powerful effects on the cost estimates. For example, when financing 80% of the TPC at a 10% interest rate over 35 years, the overall TPC is about two and a half times higher than when the TPC is directly paid from utility revenues. In the analyses, assumptions that include financing TPC usually result in rejecting the undergrounding alternative, while assumptions that do not finance TPC favor undergrounding.

Value tradeoffs are also very important when determining the results of the analysis. The model includes five value tradeoffs:

1. The value of avoiding a lost life year due to fatal cancer
2. The value of avoiding a non-fatal cancer
3. The value of avoiding an Alzheimer's case
4. The value of avoiding one hour of line failure without customer interruption (a so called "contingency")
5. The value of avoiding a person-hour of electricity interruption

These values, estimated as dollar amounts, are controversial. The models allow stakeholders a wide range of choices, for example, from $0 to $500,000 for the value of avoiding a lost life year due to fatal cancer. The results of setting higher values are to make the criterion (EMF health or outages) more influential for the analysis.

Three factual estimates had a major impact on the results of the analyses:

1. Mitigation effectiveness
2. Total project cost
3. Property values

The decision analysis models allow decision makers and stakeholders to change these variables over a wide range, starting with a base case provided in the Analytica model to a fraction and several multiples.

When considering a statewide analysis, stakeholders have the additional choices of

1. Population density
2. Miles of lines that are affected by the mitigation alternative

The policy analyses examined several alternatives for each scenario. In all cases, we included three policy options that emerged as serious policy contenders: "No change," rephasing or reconfiguring the lines, and undergrounding. We also examined other engineering alternatives – some formally, some informally. For example, we studied the effects of raising the pole height and of reducing line sag. These engineering alternatives were always inferior to the three contenders.

We also studied several land use alternatives (increasing the right-of way, increasing set backs in new developments, changing routes, engineering mitgation only for selected stretches of the line). The main result was that these land use alternatives are clearly inferior to the three contenders, since they involve large costs at fairly low or moderate benefits. A possible exception is placing restrictions on the use of an existing right-of-way, for example by prohibiting playgrounds and jogging paths in transmission line right of ways.

Which of the three contenders (no change, moderate engineering change, or undergounding) is best, depends on the stakeholder choices described above. The "No Change" alternative is best when stakeholders make the following choices:

- finance the cost of mitigation
- low discount rate
- leukemia as the only health endpoint
- low estimates of the probability of hazard and the risk ratio
- low value tradeoffs for health risks
- large multipliers for the costs of mitigation
- low or no property value impacts

Undergrounding is favored when making the following choices:

- No financing of the costs of mitigation,
- large discount rates
- all health endpoints
- high estimates of the probability of hazard and the risk ratio
- high value tradeoffs for health risks
- base case cost or low cost multipliers for undergrounding
- high property values impacts
-

For most intermediate choices, the moderate engineering changes (optimal phasing, reverse phasing, split phasing, or compact delta) are favored by the analyses.

Equity and Environmental Justice Considerations

The decision analysis approach used in this study does not lead to recommendations about resolving equity and environmental justice issues. However, it presents the analysis results in a way that allows examination of these issues and exploration of policies that address them. Most importantly, the results are always disaggregated so that the costs to groups that pay for EMF mitigation can be separated from the benefits accruing to other groups. Regarding the costs of mitigation, the analysis leaves many choices of how to distribute these costs among shareholders, ratepayers, and residents near power lines. These choices provide a powerful mechanism to address equity and environmental justice issues.

It is important to avoid the temptation to look at the “bottom line” of the analyses. The results are broken down by four criteria, which are associated with the costs and benefits accruing to different stakeholders:

1. EMF health effects – residents living near the powerlines
2. Costs – ratepayers, shareholders, or tax payers
3. Outages – all consumers of electricity
4. Property values – owners of properties near powerlines

Each mitigation alternative comes with estimated consequences in terms of EMF health effects, costs, outages, and property values. However, the mitigation alternatives do not specify the mechanism to finance the project cost. Policy makers therefore have significant control over financing mechanisms, if they decide to implement one of the mitigation alternatives. For example, they can decide to incorporate the cost of mitigation into the rate base, to have utilities (and thus their shareholders) pay for this without a rate increase, or to restrict payments to subsets of electricity users.

Each of these alternatives has significant equity and environmental justice implications. For example, if all ratepayers pay for mitigation, they will, in effect, pay restitution to people who have been negatively affected by the possible property value and health impacts of EMF exposure. They will also pay for the possible property values increase of those who bought homes that were devalued due to the EMF issue.

To illustrate how complicated this issue is, consider a homeowner who bought a house near a power line in 1960, well aware of the visual impacts of the line, but unaware of the EMF issue. A mitigation alternative that would lead to undergrounding the line would be appropriate, if EMF poses a health hazard, and it thus would provide a restitution of any loss of value of his house because of EMFs fears. However, it would also provide a "windfall" to the homeowner by eliminating the visual impacts of the powerline, which existed when the home was purchased – presumably at a reduced price. An owner who bought the house cheaply in 1990 during the height of the worries about EMF might receive a windfall in property values for both esthetic and EMF fear reasons, if the line is placed underground.

It is therefore not simply a matter of counting or not counting property values, it also is a matter of deciding who should pay for undergrounding, and who should benefit from the possible property value benefits of undergrounding. Similarly, if EMFs are not mitigated, and homeowners are successful in extracting restitution for any alleged losses in property values, decisions have to be made about who should receive the restitution (e.g., only homeowners who experienced a demonstrated loss due to EMF issues) and who should pay for it (e.g., shareholders and/or rate payers).

Considering environmental justice adds another layer of complexity. Environmental justice asks for special protection for the most vulnerable, the most susceptible, the poor, and people of color. This is not merely an equity issue but it invokes fundamental moral and ethical principles. The workshop on environmental justice held as part of this project addressed these issue. One of the key policy conclusions from this workshop was that racial and socioeconomic minorities should receive priority when making decisions about protecting health and well-being.
In practice, when considering EMF mitigation, environmental justice proponents ask that poor people and people of color should have priority when considering mitigation and that actions should be avoided that may pose additional burdens on their health and well being.

Development of the Simplified Models

The Analytica models made clear that only a few criteria mattered when choosing among the policy alternatives and they identified the key variables that influenced the decision as described in the previous section. Reviewers suggested developing simplified models that would strip the Analytica models from their unnecessary complexities, while retaining the key choices that make a difference to the model results. These models should focus on the three policy contenders and the four criteria that mattered.

An additional benefit of developing such simplified models was to create an opportunity to improve the roll-up from the local models to statewide conclusions. With the Analytica models, this was an artificial exercise, since they were specifically tailored to a local condition. With the simplified models this roll-up can be done more realistically by creating generalizeable “building blocks” based on the local scenarios.

The simplified local models were written in EXCEL (for a list of all EXCEL models, see Appendix A). The raw data for these EXCEL models come from the base case runs of the Analytica models.

The EXCEL models have a very simple and user-friendly interface. All user controls are in the form of either simple yes-no choices (for the selection of criteria) or in the form of sliders (for the selection of numerical values). Graphical displays as well as their numerical equivalents are dynamically updated as the user makes these changes.

The EXCEL models provide three views of the analysis:

1. A stacked bar chart of the equivalent costs for each of the three EMF mitigation alternatives, broken down by the four criteria (see Figure 2)
2. A cost-effectiveness plot that shows how the health risks are reduced as a function of total project cost (see Figure 3)
3. A sensitivity analysis graph that shows, which alternative is preferred as a function of the probability of a hazard (see Figure 4)

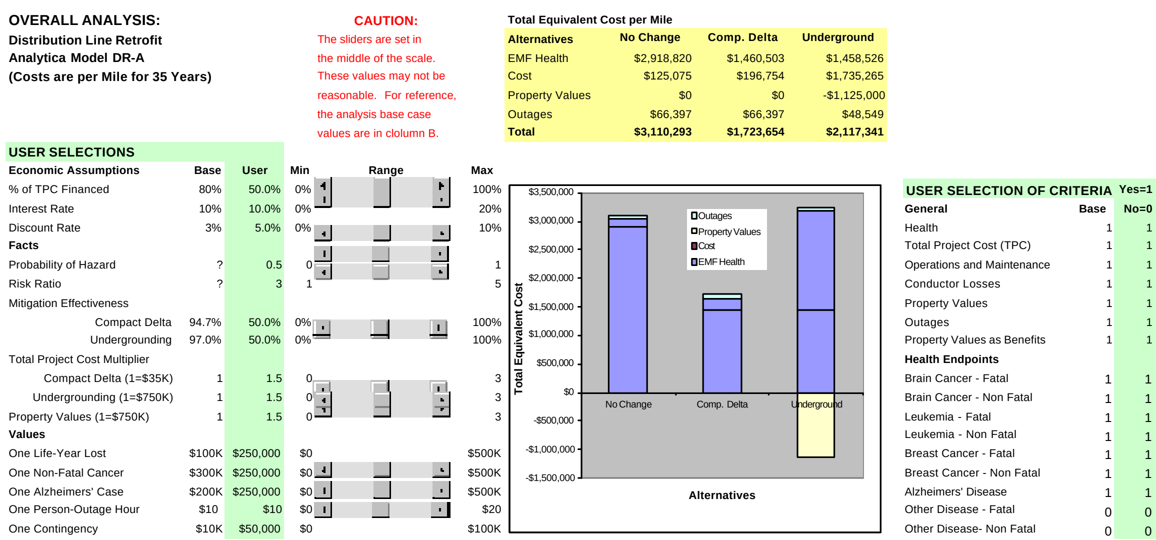
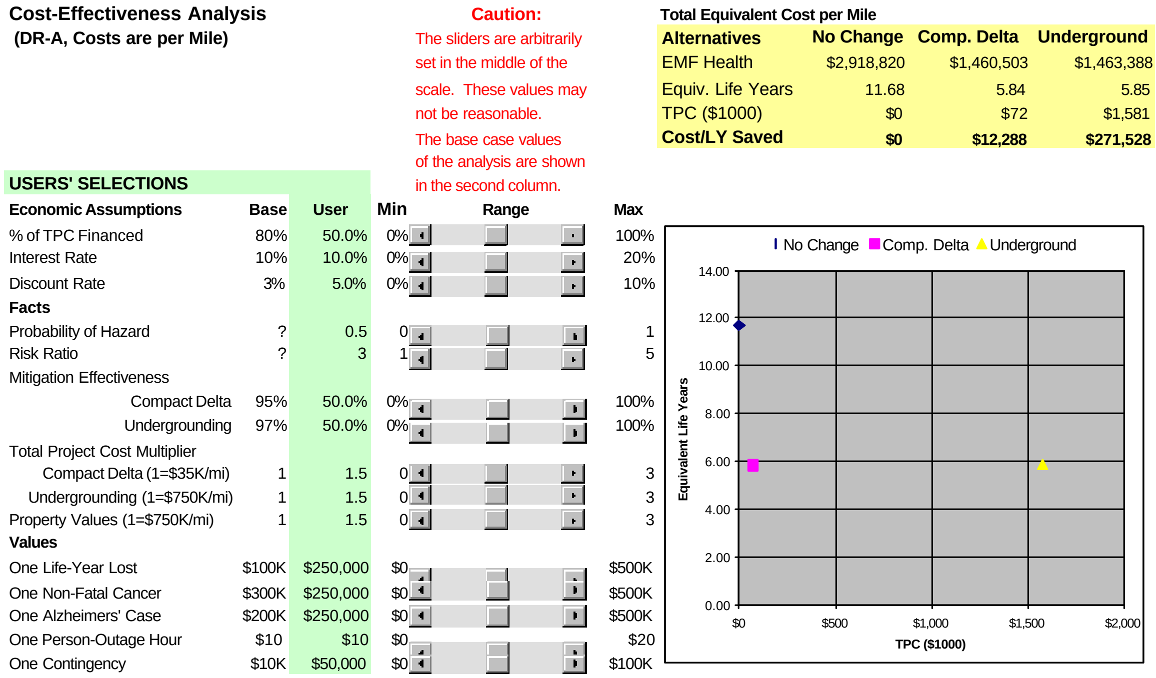


Figure 2: Stacked Bar Chart View of the Simplified Distribution Line Model DR-A



Cost-Effectiveness Analysis
(DR-A, Costs are per Mile)

Caution:
The sliders are arbitrarily set in the middle of the scale. These values may not be reasonable.
The base case values of the analysis are shown in the second column.

Total Equivalent Cost per Mile

Alternatives	No Change	Comp. Delta	Underground
EMF Health	$2,918,820	$1,460,503	$1,463,388
Equiv. Life Years	11.68	5.84	5.85
TPC ($1000)	$0	$72	$1,581
Cost/LY Saved	**$0**	**$12,288**	**$271,528**

USERS' SELECTIONS

Economic Assumptions	Base	User	Min	Range	Max
% of TPC Financed	80%	50.0%	0%		100%
Interest Rate	10%	10.0%	0%		20%
Discount Rate	3%	5.0%	0%		10%
Facts					
Probability of Hazard	?	0.5	0		1
Risk Ratio	?	3	1		5
Mitigation Effectiveness					
Compact Delta	95%	50.0%	0%		100%
Undergrounding	97%	50.0%	0%		100%
Total Project Cost Multiplier					
Compact Delta (1=$35K/mi)	1	1.5	0		3
Undergrounding (1=$750K/mi)	1	1.5	0		3
Property Values (1=$750K/mi)	1	1.5	0		3
Values					
One Life-Year Lost	$100K	$250,000	$0		$500K
One Non-Fatal Cancer	$300K	$250,000	$0		$500K
One Alzheimers' Case	$200K	$250,000	$0		$500K
One Person-Outage Hour	$10	$10	$0		$20
One Contingency	$10K	$50,000	$0		$100K

Figure 3: Cost-Effectiveness View of the Simplified Distribution Line Model DR-A

In addition to these figures, numerical tables are provided that show, for example, the total equivalent cost of a mitigation alternative (Figure 2, on top of the bar chart), or the cost effectiveness of the mitigation options (Figure 3, on top of the bar chart). Users can change the numerical inputs on the left of the graph using the sliders and EXCEL dynamically updates the graph. The user can also change the choice of criteria in the table to the right of the graph.

Sensitivity Analysis of p(Hazard)
(DR-A, Costs are per mile)

Caution:
The sliders are arbitrarily set in the middle of the scale. These values may not be reasonable. The base case values of the analysis are shown in the second column.

Total Equivalent Cost Per Mile

Alternatives	No Change	Comp. Delta	Underground
EMF Health	$0	$0	$0
EMF Health	$5,837,640	$2,921,005	$2,917,053
Cost	$125,075	$196,754	$1,735,265
Property Values	$0	$0	-$1,125,000
Outages	$66,397	$66,397	$48,549

USERS' SELECTIONS

Economic Assumptions	Base		Min	Range	Max
% of TPC Financed	80%	50.0%	0%		100%
Interest Rate	10%	10.0%	0%		20%
Discount Rate	3%	5.0%	0%		10%
Facts					
Probability of Hazard	?	1	0		1
Risk Ratio	?	3	1		5
Mitigation Effectiveness					
Compact Delta	95%	50.0%	0%		100%
Undergrounding	97%	50.0%	0%		100%
Total Project Cost Multiplier					
Compact Delta (1=$35K/mi)	1	1.5	0		3
Undergrounding (1=$750K/mi)	1	1.5	0		3
Property Values (1=$750K/mi)	1	1.5	0		3
Values					
One Life-Year Lost	$100K	$250,000	$0		$500K
One Non-Fatal Cancer	$300K	$250,000	$0		$500K
One Alzheimers' Case	$200K	$250,000	$0		$500K
One Person-Outage Hour	$10	$10	$0		$20
One Contingency	$10K	$50,000	$0		$100K

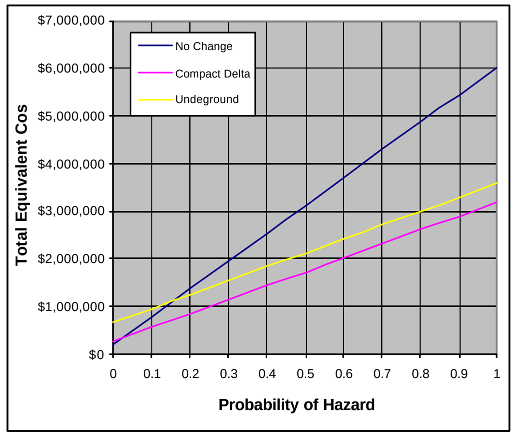


Figure 4: Sensitivity Analysis of the Probability of Hazard for the Simplified Distribution Line Model DR-A

Figure 5 shows the stacked bar chart version of the statewide analysis of distribution line retrofitting. This view is similar to Figure 2 (local statewide scenario). However, there are two important differences: First, there are several new sliders associated with statewide variables (miles of distribution lines by type and population density by type). The statewide model aggregates two distribution line models (the three wire model DR-A and the four-wire model DR-B) by multiplying their results by the number of miles and by modifying the population density. Other variables (cost multipliers and mitigation effectiveness) are controlled in the sub-models DR-A and DR-B, since they are scenario specific.

STATEWIDE ANALYSIS

Distribution Line Retrofit
(Costs are for 35 Years)

CAUTION:
The sliders are set in the middle of the scale. These values may not be reasonable. For reference, the analysis base case values are in column B.

Total Equivalent Cost - Statewide (35 Years)

Alternatives	No Change	Comp. Delta	Underground
EMF Health ($ mio)	$1,075,468	$537,891	$537,593
Cost ($ mio)	$10,006	$21,475	$268,317
Prop. Values ($ mio)	$0	$0	-$450,000
Outages ($ mio)	$26,559	$26,559	$19,420
Total ($ mio)	**$1,127,042**	**$618,137**	**$777,806**
TPC ($ mio)	$0	$11,468	$255,957

USER SELECTIONS	Base	User	Min	Range	Max
Miles of DR-A (3 Wire)	80K	80000	0		160000
Miles of DR-B (4-Wire)	80K	80000	0		160000
Pop. Density DR-A (1=8K/m2)	1	2.5	0		5
Pop Density DR-B (1=8K/m2)	1	2.5	0		5
Economic Assumptions					
% of TPC Financed	80%	50.0%	0%		100%
Interest Rate	10%	10.0%	0%		20%
Discount Rate	3%	5.0%	0%		10%
Facts					
Probability of Hazard	?	0.5	0		1
Risk Ratio	?	2.5	1		5
Values					
One Life-Year Lost	$100K	$250,000	$0		$500K
One Non-Fatal Cancer	$300K	$250,000	$0		$500K
One Alzheimers' Case	$200K	$250,000	$0		$500K
One Person-Outage Hour	$10	$10.0	$0		$20
One Contingency Hour	$10K	$50,000	$0		$100K

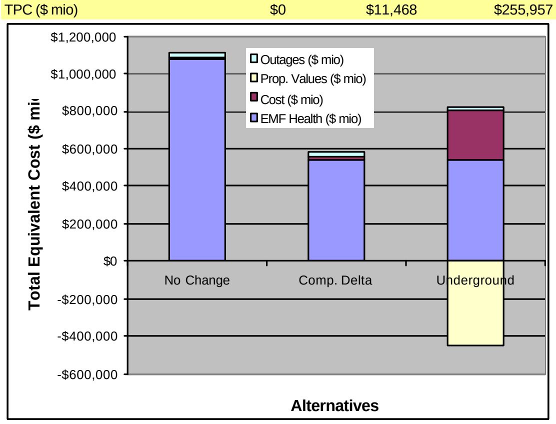


Figure 5: Stacked Bar Chart View of the Statewide Roll-Up Model (Distribution Lines)

Distribution Line Retrofitting

This section provides a walk through the simplified distribution line retrofit model in the EXCEL workbook DR-A. The corresponding Analytica model is described in chapter 8.10 of the final report. The model has two major inputs: The table of consequences and the exposure reduction effectiveness imported from the corresponding Analytica model. The table of consequences is imported into the sheet “Table 1” of the EXCEL workbook DR-A (see Table 1).

The sheet “Overall Analysis” shows the stacked bar chart version of the equivalent costs with sliders that control the key variables of the analysis. Unlike Figure 2, which showed the sliders set arbitrarily in the middle of the range of the sliders, Figure 6 shows them set at a set of values used in the Analytica models and as shown in the bar charts of the final report. With these “base case” settings, the results are virtually identical to those generated by the Analytica model. Differences will be due to omitting non-important criteria and to some minor calculation changes. Overall, these differences are less than 1% of the base case in the Analytica model.

Table 1: Data Imported from the Analytica Model DR-A

(Results are for 4 miles and 35 years, fatalities are measured in life years lost, all other estimates are simple counts or dollar values)

Distribution Line Retrofit - Scenario A: Consequences w/o EMF (no discounting/no financing)

Alternatives	No Change	Compact DELTA - All	Raise Height - All	Underground - All	Compact DELTA - Segmen
Adult Brain Cancer (Fatal)	1.35	0.07	1.08	0.04	0.79
Adult Brain Cancer (Non-Fatal)	0.08	0.00	0.07	0.00	0.05
Adult Leukemia (Fatal)	1.76	0.09	1.41	0.05	1.03
Adult Leukemia (Non-Fatal)	0.14	0.01	0.11	0.00	0.08
Breast Cancer (Fatal)	4.14	0.22	3.31	0.12	2.42
Breast Cancer (Non-Fatal)	0.86	0.05	0.69	0.03	0.50
Alzheimer	0.90	0.05	0.72	0.03	0.52
Adult Other Health Endpoint (Fatal)	0.00	0.00	0.00	0.00	0.00
Adult Other Health Endpoint (Non-Fatal)	0.00	0.00	0.00	0.00	0.00
Childhood Brain Cancer (Fatal)	0.28	0.01	0.22	0.01	0.16
Childhood Brain Cancer (Non-Fatal)	0.01	0.00	0.01	0.00	0.01
Childhood Leukemia (Fatal)	0.44	0.02	0.35	0.01	0.26
Childhood Leukemia (Non-Fatal)	0.02	0.00	0.02	0.00	0.01
Childhood Other Health Endpoint (Fatal)	0.00	0.00	0.00	0.00	0.00
Childhood Other Health Endpoint (Non-Fat	0.00	0.00	0.00	0.00	0.00
Worker - Brain Cancer (Fatal)	0.00	0.00	0.00	0.00	0.00
Worker - Brain Cancer (Non-Fatal)	0.00	0.00	0.00	0.00	0.00
Worker - Leukemia (Fatal)	0.00	0.00	0.00	0.00	0.00
Worker - Leukemia (Non-Fatal)	0.00	0.00	0.00	0.00	0.00
Fire Fatalities	0.22	0.22	0.22	0.00	0.22
Fire Injuries	0.10	0.10	0.10	0.00	0.10
Collision Fatalities	0.85	0.85	0.85	0.21	0.85
Collision Injuries	0.02	0.02	0.02	0.00	0.02
Electrocutions - Public	0.27	0.27	0.27	0.05	0.27
Construction Fatalities	0.00	0.00	0.01	0.01	0.00
Construction Injuries	0.00	0.02	0.03	0.05	0.00
Electrocutions - Workers	0.16	0.16	0.16	0.05	0.16
TPC	$0	$141,700	$338,000	$3,125,000	$35,420
O&M	$252,000	$252,000	$252,000	$210,000	$252,000
Conductor Losses	$817,400	$817,400	$817,400	$1,111,000	$817,400
Property Values	$0	$0	$0	-$3,000,000	$0
Property Loss - Fires	$15,430	$15,430	$15,430	$0	$15,430
Property Loss - Collisions	$4	$4	$4	$1	$4
Outages - Contingencies	16.24	16.24	16.24	24.65	16.24
Outages - Customer Interruptions	56770.00	56770.00	56770.00	41510.00	56770.00
Aesthetics	0.00	0.00	0.00	-4.00	0.00
Trees	0.00	0.00	0.00	-32.00	0.00
Air Pollution	0.00	0.00	0.00	-24020.00	0.00
Noise and Disruption	0.00	0.00	0.00	720.00	0.00

OVERALL ANALYSIS:
Distribution Line Retrofit
Analytica Model DR-A
(Costs are per Mile)

CAUTION:
The sliders are set in the middle of the scale. These values may not be reasonable. For reference, the analysis base case values are in clolumn B.

Total Equivalent Cost per Mile

Alternatives	**No Change**	**Comp. Delta**	**Underground**
EMF Health	$201,509	$10,688	$6,042
Cost	$164,132	$234,358	$1,751,499
Property Values	$0	$0	-$750,000
Outages	$87,131	$87,131	$63,710
Total	**$452,771**	**$332,177**	**$1,071,251**

USER SELECTIONS

Economic Assumptions	**Base**	**User**	**Min**	**Range**	**Max**
% of TPC Financed	80%	80.0%	0%		100%
Interest Rate	10%	10.0%	0%		20%
Discount Rate	3%	3.0%	0%		10%
Facts					
Probability of Hazard	?	0.1	0		1
Risk Ratio	?	2	1		5
Mitigation Effectiveness					
Compact Delta	94.7%	94.7%	0%		100%
Undergrounding	97.0%	97.0%	0%		100%
Total Project Cost Multiplier					
Compact Delta (1=$35K)	1	1	0		3
Undergrounding (1=$750K)	1	1	0		3
Property Values (1=$750K)	1	1	0		3
Values					
One Life-Year Lost	$100K	$100,000	$0		$500K
One Non-Fatal Cancer	$300K	$300,000	$0		$500K
One Alzheimers' Case	$200K	$200,000	$0		$500K
One Person-Outage Hour	$10	$10	$0		$20
One Contingency	$10K	$10,000	$0		$100K

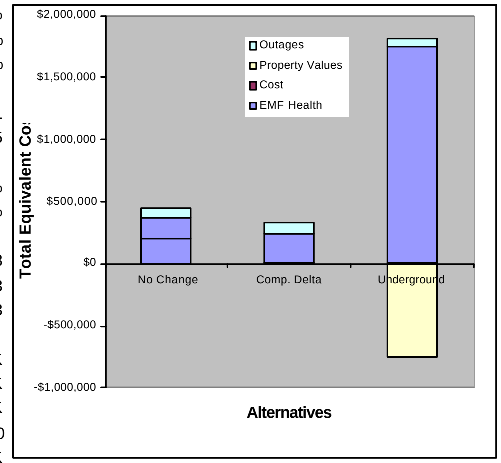


Figure 6: Stacked Bar Chart of Equivalent Costs Using the Analytica Base Case Settings in the EXCEL Model

To the left of the stacked bar chart are sliders that the user can control to change the important model parameters. For example, the user can change the probability of a hazard from 0 to 1. The graph and the corresponding numerical results in the yellow area are updated dynamically with the change of the slider position. The original setting of the sliders is in the middle of the scale. This is an arbitrary choice. The base case settings are shown in the column labeled "Base." The sliders can be adjusted to any position, including the Analytica base case settings as shown in Figure 6.

The stacked bar chart in Figure 6 corresponds to the stacked bar chart shown for one run of the Analytica model (see Final Report, Figure 8.55). The corresponding Analytica output is shown in Figure 7. This figure includes more alternatives than Figure 6 (raising pole height and mitigation for one segment only), the calculations are for four miles rather than one, and the chart includes "other" costs as well as the costs of the four major criteria. However, if one eliminates the other alternatives, the other costs, and then divides the costs in Figure 7 by 4, the results are virtually indistinguishable from those in Figure 6.

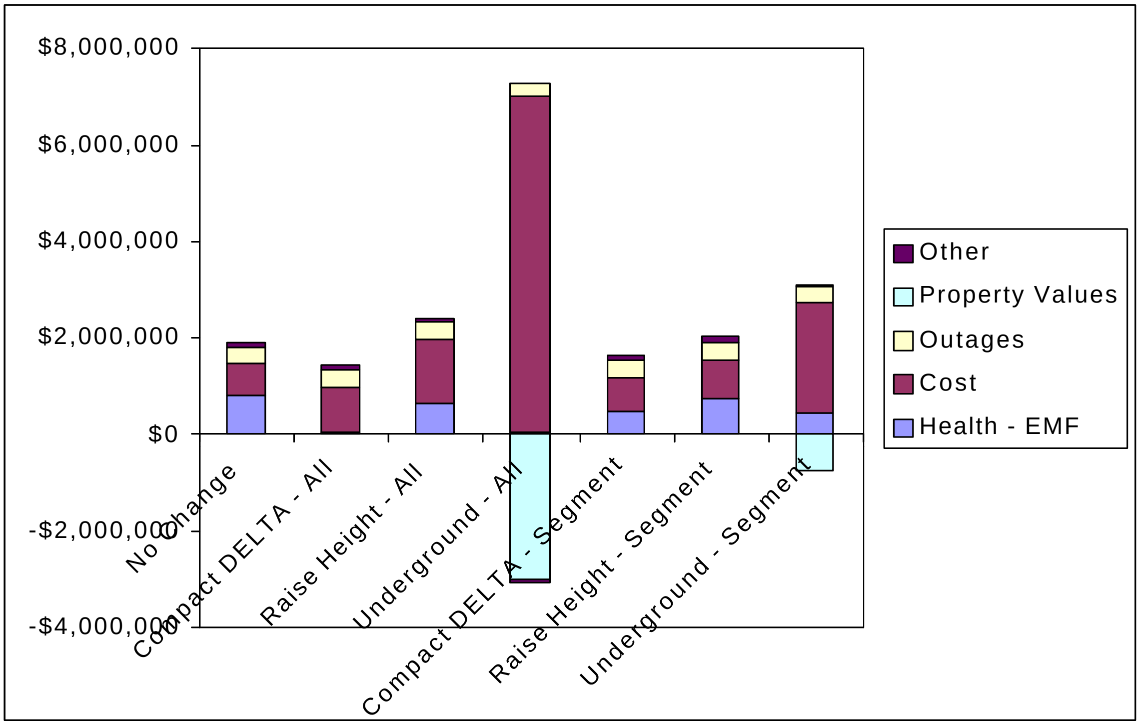


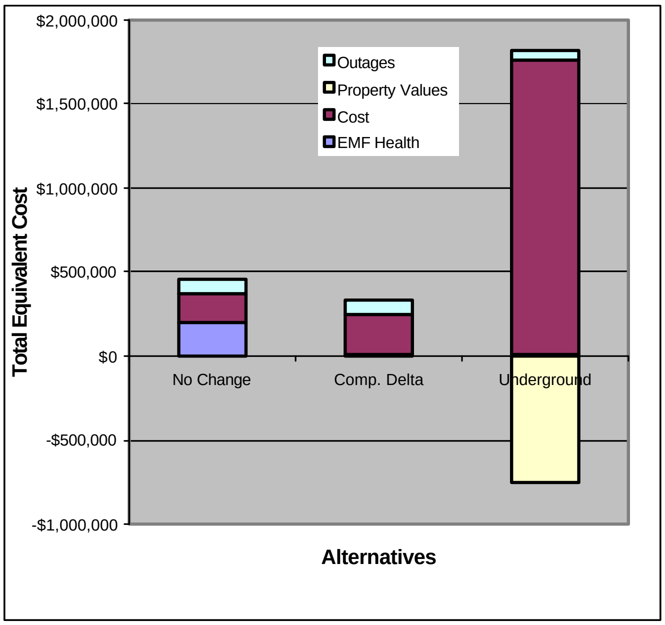
Figure 7: Stacked Bar Chart of Equivalent Costs Using the Base Case Settings in the Analytica Model (Final Report, Figure 8.55)

To select criteria in the EXCEL model, the user types a "1" next to the criterion that should be included and a "0" next to a criterion that should be excluded (Figure 8). For example, users who only wants to examine TPC among the cost components and only leukemia among the health endpoints, would type "0" next to "Operations and Maintenance" and "Conductor Losses" as well as "0" next to all but the two leukemia health endpoints. The graph and the numerical table are again updated dynamically.

In addition to selecting criteria, users can also select whether property values are counted as benefits of undergrounding or as costs existing overhead lines. This can be done by selecting "0" next to the row labeled "Property Values as Benefits?" The result of this change is shown in Figure 9.

Total Equivalent Cost per Mile

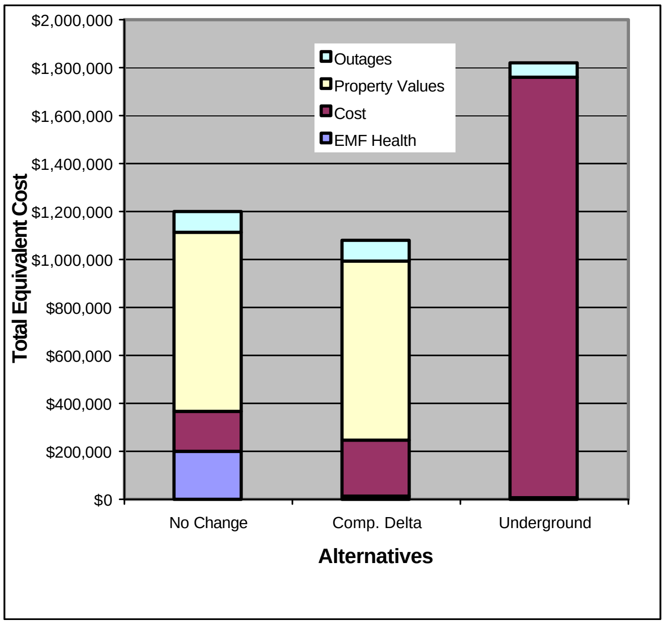
Alternatives	No Change	Comp. Delta	Underground
EMF Health	$201,509	$10,688	$6,042
Cost	$164,132	$234,358	$1,751,499
Property Values	$0	$0	-$750,000
Outages	$87,131	$87,131	$63,710
Total	**$452,771**	**$332,177**	**$1,071,251**



USER SELECTION OF CRITERIA		Yes=1
General	**Base**	**No=0**
Health	1	1
Total Project Cost (TPC)	1	1
Operations and Maintenance	1	1
Conductor Losses	1	1
Property Values	1	1
Outages	1	1
Property Values as Benefits	1	1
Health Endpoints		
Brain Cancer - Fatal	1	1
Brain Cancer - Non Fatal	1	1
Leukemia - Fatal	1	1
Leukemia - Non Fatal	1	1
Breast Cancer - Fatal	1	1
Breast Cancer - Non Fatal	1	1
Alzheimers' Disease	1	1
Other Disease - Fatal	0	0
Other Disease- Non Fatal	0	0

Figure 8: Stacked Bar Chart and User Selection of Criteria
(User selects “0”to exclude a criterion, “1” to include it)

Total Equivalent Cost per Mile			
Alternatives	**No Change**	**Comp. Delta**	**Underground**
EMF Health	$201,509	$10,688	$6,042
Cost	$164,132	$234,358	$1,751,499
Property Values	$750,000	$750,000	$0
Outages	$87,131	$87,131	$63,710
Total	**$1,202,771**	**$1,082,177**	**$1,821,251**



USER SELECTION OF CRITERIA		Yes=1
General	**Base**	**No=0**
Health	1	1
Total Project Cost (TPC)	1	1
Operations and Maintenance	1	1
Conductor Losses	1	1
Property Values	1	1
Outages	1	1
Property Values as Benefits	1	0
Health Endpoints		
Brain Cancer - Fatal	1	1
Brain Cancer - Non Fatal	1	1
Leukemia - Fatal	1	1
Leukemia - Non Fatal	1	1
Breast Cancer - Fatal	1	1
Breast Cancer - Non Fatal	1	1
Alzheimers' Disease	1	1
Other Disease - Fatal	0	0
Other Disease- Non Fatal	0	0

Figure 9: Stacked Bar Chart with Property Values as Costs of "No Change" for DR-A for the Analytica Base Case
(User selects "0" for "Property Values as Benefits")

The sheet "Cost-Effectiveness Analysis" compares the total project cost (TPC) with the possible health risk reduction. Figure 10 shows the life years lost as a function of the TPC. It illustrates that a substantial risk reduction can be achieved with a fairly cheap mitigation measure (compact delta), while undergrounding costs much more with little additional risk reduction benefits.

Cost-Effectiveness Analysis
(DR-A, Costs are per Mile)

Caution:
The sliders are arbitrarily set in the middle of the scale. These values may not be reasonable. The base case values of the analysis are shown in the second column.

Total Equivalent Cost per Mile

Alternatives	No Change	Comp. Delta	Underground
EMF Health	$403,018	$21,376	$12,124
Equiv. Life Years	4.03	0.21	0.12
TPC ($1000)	$0	$70	$1,549
Cost/LY Saved	**$0**	**$18,401**	**$396,207**

USERS' SELECTIONS

Economic Assumptions	**Base**	**User**	**Min**	**Range**	**Max**
% of TPC Financed	80%	80.0%	0%		100%
Interest Rate	10%	10.0%	0%		20%
Discount Rate	3%	3.0%	0%		10%
Facts					
Probability of Hazard	?	0.2	0		1
Risk Ratio	?	2	1		5
Mitigation Effectiveness					
Compact Delta	95%	94.7%	0%		100%
Undergrounding	97%	97.0%	0%		100%
Total Project Cost Multiplier					
Compact Delta (1=$35K/mi)	1	1	0		3
Undergrounding (1=$750K/mi)	1	1	0		3
Property Values (1=$750K/mi)	1	1	0		3
Values					
One Life-Year Lost	$100K	$100,000	$0		$500K
One Non-Fatal Cancer	$300K	$300,000	$0		$500K
One Alzheimers' Case	$200K	$200,000	$0		$500K
One Person-Outage Hour	$10	$10	$0		$20
One Contingency	$10K	$10,000	$0		$100K

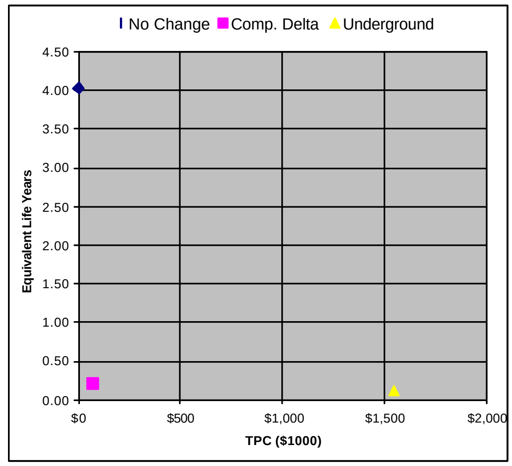


Figure 10: Cost-Effectiveness Analysis for DR-A (Analytica Base Case)

Figure 11 shows how the total equivalent cost changes as a function of the probability that EMF is a hazard. A line in this graph represents the total equivalent cost for one policy alternative as a function of the probability of a hazard. For each probability, the best alternative is the one with the lowest line (least total equivalent cost). This graph shows that for all but extremely low probabilities, the "Compact Delta" alternative has the lowest equivalent cost.

Sensitivity Analysis of p(Hazard)
(DR-A, Costs are per mile)

Caution:
The sliders are arbitrarily set in the middle of the scale. These values may not be reasonable.
The base case values of the analysis are shown in the second column.

Total Equivalent Cost Per Mile

Alternatives	No Change	Comp. Delta	Underground
EMF Health	$0	$0	$0
EMF Health	$2,015,091	$106,882	$60,416
Cost	$164,132	$234,358	$1,751,499
Property Values	$0	$0	-$750,000
Outages	$87,131	$87,131	$63,710

USERS' SELECTIONS

Economic Assumptions	Base		Min	Range	Max
% of TPC Financed	80%	80.0%	0%		100%
Interest Rate	10%	10.0%	0%		20%
Discount Rate	3%	3.0%	0%		10%
Facts					
Probability of Hazard	?	1	0		1
Risk Ratio	?	2	1		5
Mitigation Effectiveness					
Compact Delta	95%	94.7%	0%		100%
Undergrounding	97%	97.0%	0%		100%
Total Project Cost Multiplier					
Compact Delta (1=$35K/mi)	1	1	0		3
Undergrounding (1=$750K/mi)	1	1	0		3
Property Values (1=$750K/mi)	1	1	0		3
Values					
One Life-Year Lost	$100K	$100,000	$0		$500K
One Non-Fatal Cancer	$300K	$300,000	$0		$500K
One Alzheimers' Case	$200K	$200,000	$0		$500K
One Person-Outage Hour	$10	$10	$0		$20
One Contingency	$10K	$10,000	$0		$100K

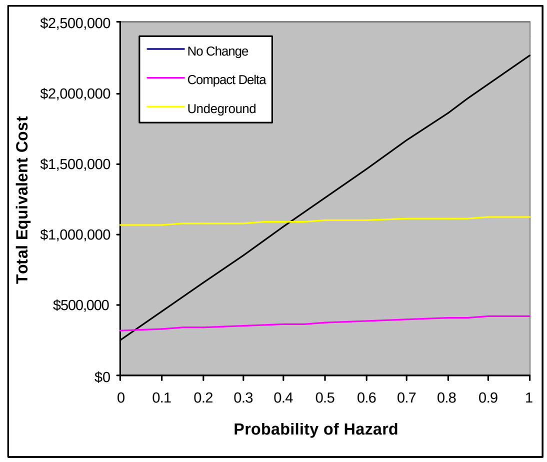


Figure 11: Sensitivity Analysis of p(Hazard)
(Analytica Base Case)

There are two distribution line retrofit models: DR-A, described above, involves a distribution line with three wires and no or little imbalances, and DR-A involves a distribution line with four wires and about 25% imbalance. The latter model is in the EXCEL workbook DR-B. The main difference is that the fields are generally higher for DR-B (more imbalance) and that the field reduction effectiveness is generally lower (less field cancellation due to compaction). Otherwise the two models are identical.

The EXCEL workbook “DR Statewide” presents a “roll up” from these two scenarios to the statewide level. To accomplish this roll up, the user first specifies the the cost and the effectiveness of the mitigation alternatives. The user can adjust these variables with sliders in the two sheets “Overall Analysis DR-A” and “Overall Analysis DR-B.” All other variables are blocked out in these two sheets (see Figure 12).

Users of the statewide roll up model should consider DR-A and DR-B as two building blocks to define typical distribution line scenarios. They can either use the Analytica default values or any other values to define the cost and effectiveness of mitigation in the two scenarios.

OVERALL ANALYSIS:
Distribution Line Retrofit
Analytica Model DR-A
(Costs are per Mile for 35 Years)

CAUTION:
The sliders are set in the middle of the scale. These values may not be reasonable. For reference, the analysis base case values are in clolumn B.

Total Equivalent Cost per Mile (35 Years)

Alternatives	No Change	Comp. Delta	Underground
EMF Health	$201,509	$10,688	$6,042
Cost	$164,132	$234,358	$1,751,499
Property Values	$0	$0	-$750,000
Outages	$87,131	$87,131	$63,710
Total	**$452,771**	**$332,177**	**$1,071,251**
TPC	$0	$70,227	$1,548,752

USER SELECTIONS

Economic Assumptions	Base	User	Min	Range	Max
% of TPC Financed	80%	80.0%	0%		100%
Interest Rate	10%	10.0%	0%		20%
Discount Rate	3%	3.0%	0%		10%
Facts					
Probability of Hazard	?	0.1	0		1
Risk Ratio	?	2	1		5
Mitigation Effectiveness					
Compact Delta	94.7%	94.7%	0%		100%
Undergrounding	97.0%	97.0%	0%		100%
Total Project Cost Multiplier					
Compact Delta (1=$35K)	1	1	0		3
Undergrounding (1=$750K)	1	1	0		3
Property Values (1=$750K)	1	1	0		3
Values					
One Life-Year Lost	$100K	$100,000	$0		$500K
One Non-Fatal Cancer	$300K	$300,000	$0		$500K
One Alzheimers' Case	$200K	$200,000	$0		$500K
One Person-Outage Hour	$10	$10	$0		$20
One Contingency	$10K	$10,000	$0		$100K

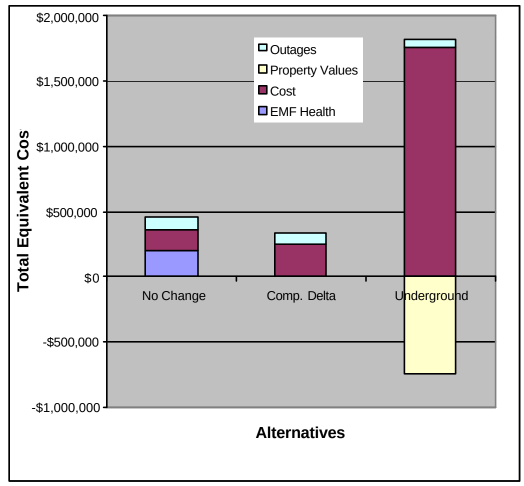


Figure 12: User Controls of Variables that are Specific to the Distribution Line Scenarios DR-A and the DR-B (Analytica Base Case)

With these two building blocks, the user can then proceed to the sheet "Statewide Analysis." In this sheet all the variables that are common to DR-A And DR-B can be controlled with sliders (see Figure 13). These are, first, all the variables that were were used in the per-mile analyses of DR-A and DR-B (economic assumptions, facts, values, and what criteria to include). In addition, there are four new variables:

1. Miles of DR-A type distribution lines
2. Miles of DR-B type distribution lines
3. Population density multiplier for DR-A type distribution lines
4. Population density for DR-B type distribution lines

Notice that the label DR-A and DR-B does not necessarily reflect any more the Analytica base cases, but whatever "building block" assumption the user wants to make about two distribution line retrofitting scenarios.

There are 160,000 miles of primary distribution lines in California (see final report, chapter 2). We estimated that between 5% and 10% (8,000 and 16,000 miles) of these lines might require retrofitting. The user is left with a wide variety of choices for the number of miles that would require retrofitting, ranging from 0 miles to 160,000 miles for DR-A or DR-B type scenarios. When making these adjustments, the user needs to take care that the total number of miles to be retrofit does not exceed 160,000 miles – in fact it should be substantially less. In Figure 13, we set the sliders for the number of miles to be retrofit at 8,000 miles for both DR-A and DR-B scenarios, based on reasoning explained in Chapter 12 of the final report.

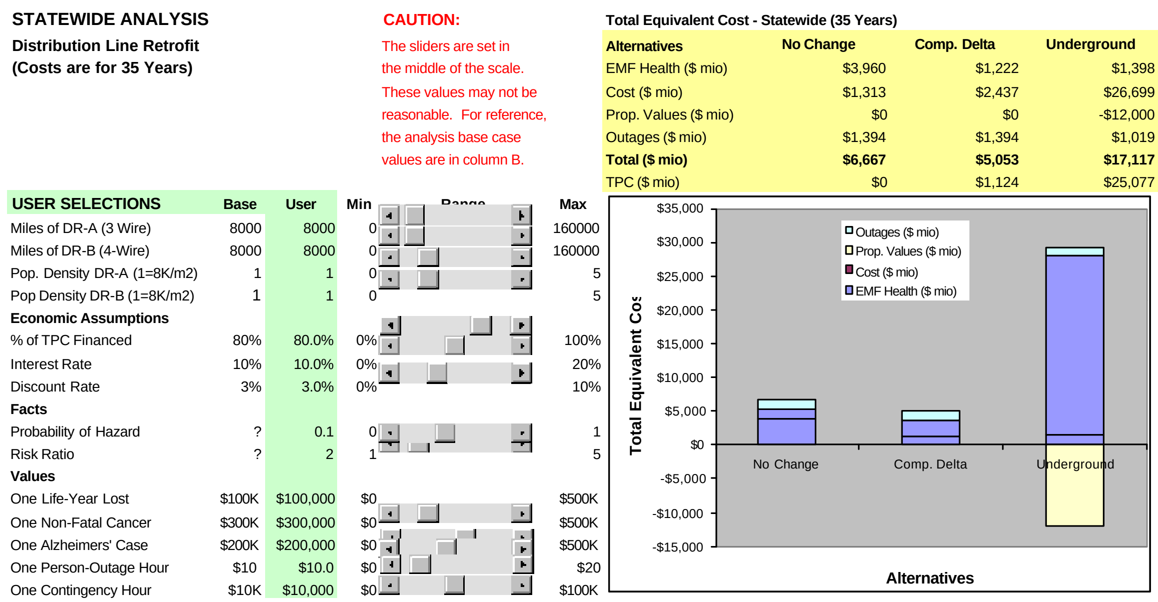


Figure 13: User Controls for the Statewide Analysis of Distribution Line Retrofitting (Analytica Base Case)

Another important variable that controls the statewide impact of the analysis is the population density. In the local scenarios we used a fairly high population density of about 8,000 people per square mile, because we were primarily concerned about distribution lines in higher density residential areas. However, population densities in residential areas of California vary widely from about 2,000 people per square mile (e.g., Irvine) to 10,000 people per square mile (e.g., Long Beach) to 20,000 or more people per square mile (e.g., San Francisco). When conducting a statewide analysis average population densities in residential areas should be used, which are probably closer to 2,000 to 4,000 people per square mile. The statewide model allows making separate population density adjustments for DR-A and DR-B scenarios.

There are two additional sheets in the workbook "DR Statewide," one showing the statewide cost-benefit analysis and one showing the statewide analysis of the sensitivity of the probability of a hazard. These two sheets are very similar to the sheets in the local analyses DR-A and DR-B, except that the overall equivalent costs are multiplied by the number of miles of DR-A and DR-B type lines.

Transmission Line Retrofitting

The simplified EXCEL models for transmission lines are identical in structure and logic to the simplified EXCEL models for distribution lines. We will briefly describe the 69kV transmission line model (TR-69), followed by the statewide transmission line retrofitting analysis. The corresponding Analytica model is described in chapter 8.3 of the final report.

Table 2 shows the Analytica data that are imported into the EXCEL model, using the Analytica base case assumptions. Figure 14 shows the sheet "Overall Analysis" of the EXCEL workbook TR-69. This analysis is for retrofitting a 69kV transmission in a horizontal configuration on a wooden street-side pole. The "moderate" alternative is to split phase this line. Figures 15 and 16 show the cost-effectiveness analysis and the p(hazard) sheets of this workbook.

Table 2: Data Imported from Analytica Model TR-69

(Results are for 15 miles and 35 years, fatalities are measured in life years lost, all other estimates are simple counts or dollar values)

69kV Retrofit: Consequences w/o EMF (no discounting/no financing)

Alternatives	No Change	Optimal Phasing	Underground - All
Adult Brain Cancer (Fatal)	16.84	3.07	0.32
Adult Brain Cancer (Non-Fatal)	1.05	0.19	0.02
Adult Leukemia (Fatal)	22.00	4.01	0.41
Adult Leukemia (Non-Fatal)	1.80	0.33	0.03
Breast Cancer (Fatal)	51.86	9.45	0.97
Breast Cancer (Non-Fatal)	10.80	1.97	0.20
Alzheimer	11.22	2.04	0.21
Adult Other Health Endpoint (Fatal)	0.00	0.00	0.00
Adult Other Health Endpoint (Non-Fatal)	0.00	0.00	0.00
Childhood Brain Cancer (Fatal)	4.12	0.75	0.08
Childhood Brain Cancer (Non-Fatal)	0.20	0.04	0.00
Childhood Leukemia (Fatal)	6.48	1.18	0.12
Childhood Leukemia (Non-Fatal)	0.33	0.06	0.01
Childhood Other Health Endpoint (Fatal)	0.00	0.00	0.00
Childhood Other Health Endpoint (Non-Fat	0.00	0.00	0.00
Worker - Brain Cancer (Fatal)	0.00	0.00	0.00
Worker - Brain Cancer (Non-Fatal)	0.00	0.00	0.00
Worker - Leukemia (Fatal)	0.00	0.00	0.00
Worker - Leukemia (Non-Fatal)	0.00	0.00	0.00
Fire Fatalities	0.82	0.82	0.00
Fire Injuries	0.36	0.36	0.00
Collision Fatalities	3.18	3.18	0.80
Collision Injuries	0.06	0.06	0.02
Electrocutions - Public	1.00	1.00	0.18
Construction Fatalities	0.00	0.01	3.96
Construction Injuries	0.00	0.06	20.10
Electrocutions - Workers	0.59	0.59	0.19
TPC	$0	$25,880	$24,750,000
O&M	$945,000	$945,000	$787,500
Conductor Losses	$13,080,000	$13,080,000	$11,480,000
Property Values	$0	$0	-$25,280,000
Property Loss - Fires	$57,850	$57,850	$0
Property Loss - Collisions	$16	$16	$4
Outages - Contingencies	97.46	97.46	90.83
Outages - Customer Interruptions	194900.00	194900.00	181700.00
Aesthetics	0.00	0.00	-45.00
Trees	0.00	0.00	-120.00
Air Pollution	0.00	0.00	-105100.00
Noise and Disruption	0.00	758.30	35390.00

OVERALL ANALYSIS:
Transmission Line Retrofit
Analytica Model TR-69
(Costs are per Mile)

CAUTION:
The sliders are set in the middle of the scale. These values may not be reasonable. For reference, the analysis base case values are in clolumn B.

Total Equivalent Cost per Mile

Alternatives	No Change	Split Phase	Underground
EMF Health	$3,983,452	$1,992,033	$1,990,676
Cost	$233,512	$444,576	$1,848,486
Property Values	$0	$0	-$1,264,000
Outages	$300,973	$300,973	$78,365
Total	**$4,517,937**	**$2,737,583**	**$2,653,527**

USER SELECTIONS

Economic Assumptions	Base	User	Min	Range	Max
% of TPC Financed	80%	50.0%	0%		100%
Interest Rate	10%	10.0%	0%		20%
Discount Rate	3%	5.0%	0%		10%
Facts					
Probability of Hazard	?	0.5	0		1
Risk Ratio	?	3	1		5
Mitigation Effectiveness					
Split Phasing	96.4%	50.0%	0%		100%
Undergrounding	90%	50.0%	0%		100%
Total Project Cost Multiplier					
Split Phasing(1=155K)	1	1.5	0		3
Undergrounding (1=$775K)	1	1.5	0		3
Property Values (1=$1,264K)	1	1.5	0		3
Values					
One Life-Year Lost	$100K	$250,000	$0		$500K
One Non-Fatal Cancer	$300K	$250,000	$0		$500K
One Alzheimers' Case	$200K	$250,000	$0		$500K
One Person-Outage Hour	$10	$10	$0		$20
One Contingency	$10K	$50,000	$0		$100K

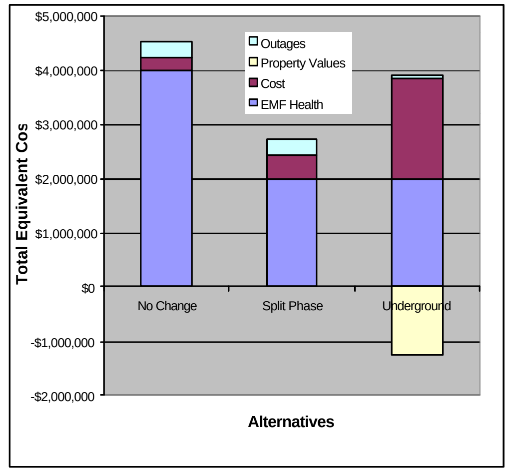


Figure 14: Overall Analysis Sheet of The EXCEL Model TR-69

Cost-Effectiveness Analysis
(TR-69, Costs are per Mile)

Caution:
The sliders are arbitrarily set in the middle of the scale. These values may not be reasonable. The base case values of the analysis are shown in the second column.

Total Equivalent Cost per Mile

Alternatives	No Change	Split Phase	Underground
EMF Health	$3,983,452	$1,992,033	$1,990,676
Equiv. Life Years	15.93	7.97	7.96
TPC ($1000)	$0	$313,084	$1,570,140
Cost/LY Saved	**$0**	**$39,304**	**$196,979**

USERS' SELECTIONS

Economic Assumptions	Base	User	Min	Range	Max
% of TPC Financed	80%	50.0%	0%		100%
Interest Rate	10%	10.0%	0%		20%
Discount Rate	3%	5.0%	0%		10%
Facts					
Probability of Hazard	?	0.5	0		1
Risk Ratio	?	3	1		5
Mitigation Effectiveness					
Split Phasing	96.4%	50.0%	0%		100%
Undergrounding	90.0%	50.0%	0%		100%
Total Project Cost Multiplier					
Split Phasing(1=155K)	1	1.5	0		3
Undergrounding (1=$775K)	1	1.5	0		3
Property Values (1=$1,264K)	1	1.5	0		3
Values					
One Life-Year Lost	$100K	$250,000	$0		$500K
One Non-Fatal Cancer	$300K	$250,000	$0		$500K
One Alzheimers' Case	$200K	$250,000	$0		$500K
One Person-Outage Hour	$10	$10	$0		$20
One Contingency	$10K	$50,000	$0		$100K

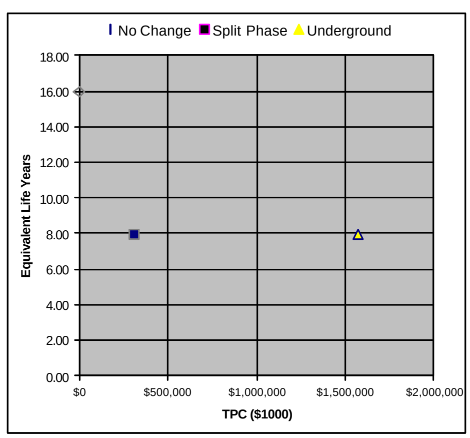


Figure 15: Cost-Effectivenes Sheet of The EXCEL Model TR-69

Sensitivity Analysis of p(Hazard)
(TR-69, Costs are per mile)

Caution:
The sliders are arbitrarily set in the middle of the scale. These values may not be reasonable. The base case values of the analysis are shown in the second column.

Total Equivalent Cost Per Mile

Alternatives	No Change	Split Phase	Underground
EMF Health	$0	$0	$0
EMF Health	$7,966,903	$3,984,067	$3,981,351
Cost	$875,669	$806,181	$2,613,937
Property Values	$0	$0	-$1,264,000
Outages	$300,973	$300,973	$78,365

USERS' SELECTIONS

Economic Assumptions	Base	USER	Min	Range	Max
% of TPC Financed	80%	50.0%	0%		100%
Interest Rate	10%	10.0%	0%		20%
Discount Rate	3%	5.0%	0%		10%
Facts					
Probability of Hazard	?	1	0		1
Risk Ratio	?	3	1		5
Mitigation Effectiveness					
Split Phasing	96.35%	50.0%	0%		100%
Undergrounding	90.01%	50.0%	0%		100%
Total Project Cost Multiplier					
Split Phasing(1=155K)	1	1.5	0		3
Undergrounding (1=$775K)	1	1.5	0		3
Property Values (1=$1,264K)	1	1.5	0		3
Values					
One Life-Year Lost	$100K	$250,000	$0		$500K
One Non-Fatal Cancer	$300K	$250,000	$0		$500K
One Alzheimers' Case	$200K	$250,000	$0		$500K
One Person-Outage Hour	$10	$10	$0		$20
One Contingency	$10K	$50,000	$0		$100K

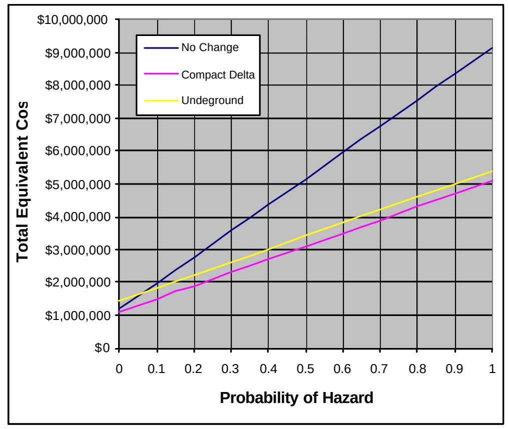


Figure 16: p(Hazard) Sheet of The EXCEL Model TR-69

Similar models were developed based on two other transmission line retrofitting models, built in Analytica. The model TR-115 examined a 15-mile stretch of a 115kV transmission line on a cleared right-of-way in a fairly densely populated suburban area. This was a double circuit line with two mitigation alternatives: optimal phasing or undergrounding. The model TR-230 examined a 50-mile stretch of 230kV line that passed through 40 miles of uninhabited land and 10 miles of mixed-use land (industrial, urban, and suburban).

These three scenarios were used as “building blocks” to create a statewide analysis in the EXCEL workbook “TR Statewide.” As in the distribution line scenarios, the model user can adjust each of the three sub-models (TR-69, TR-115, and TR-230) to define the specific characteristics of these building blocks. In particular, the user can control mitigation effectiveness and cost in each of the three scenarios. The results are then rolled up to a statewide level using data on the miles of the types of transmission lines represented in the three scenarios.

Figure 17 shows how the model user can control the statewide analysis. In addition to the variables that could be controlled within each scenario, the user can now choose the miles of affected transmission lines for each scenario and the population density.

STATEWIDE ANALYSIS

Transmission Line Retrofit
(Costs are for 35 Years)

CAUTION:

The sliders are set in the middle of the scale. These values may not be reasonable. For reference, the analysis base case values are in column B.

Total Equivalent Cost - Statewide (35 Years)

Alternatives	**No Change**	**Phasing**	**Underground**
EMF Health ($ mio)	$57,636	$28,843	$28,833
Cost ($ mio)	$1,445	$1,660	$19,372
Prop. Values ($ mio)	$0	$0	-$11,255
Outages ($ mio)	$2,635	$2,635	$2,156
Total ($ mio)	**$61,716**	**$33,138**	**$39,107**
TPC ($ mio)	$0	$317	$16,918

USER SELECTIONS	**Base**	**User**	**Min**	**Range**	**Max**
Miles of TR-69 (Sgl. Circuit)	884	1000	0		2000
Miles of TR-115 (Dbl. Circuit)	433	1000	0		2000
Miles of TR-230 (Dbl. Circuit)	376	1000	0		2000
Pop Density TR-69 (1=4K/sqm)	1	2.5	0		5
Pop Density TR-115 (1=4K/sqm)	1	2.5	0		5
Pop Density TR-230 (1=3K/sqm)	1	2.5	0		5
Economic Assumptions					
% of TPC Financed	80%	50.0%	0%		100%
Interest Rate	10%	10.0%	0%		20%
Discount Rate	3%	5.0%	0%		10%
Facts					
Probability of Hazard	?	0.5	0		1
Risk Ratio	?	2.5	0		5
Values					
One Life-Year Lost	$100K	$250,000	$0		$500K
One Non-Fatal Cancer	$300K	$250,000	$0		$500K
One Alzheimers' Case	$200K	$250,000	$0		$500K
One Person-Outage Hour	$10	$10.0	$0		$20
One Contingency Hour	$10K	$50,000	$0		$100K

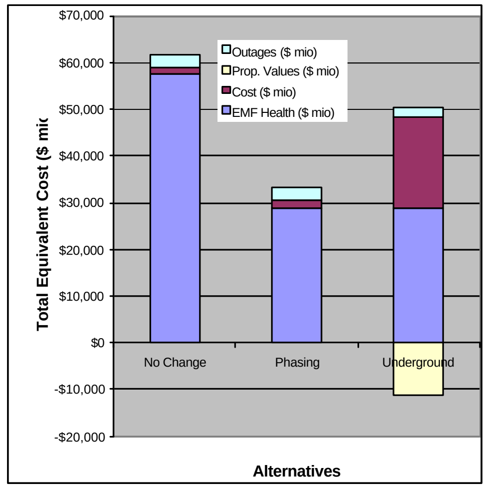


Figure 17: Statewide Analysis for Transmission Lines
(Sliders are Arbitrarily Set at Middle of the Range)

This statewide analysis has to be interpreted very cautiously. First, it is not clear whether the three “building blocks” are representative of the types of lines and the population and exposure characteristics in California. The base case settings of the Analytica model are probably reasonable approximations of some realistic local scenarios, but they are unlikely to represent all of California. When using the statewide analysis, the user should create “building blocks” that are more representative of the power grid in California.

One special concern is related to how many miles of transmission lines are single circuit vs. double circuit lines. In the Analytica base case analysis, we assume that all 69kV lines are single circuit and thus candidates for split phasing, and that all 115kV and 230kV lines are double circuit and thus candidates for reverse or optimal phasing. Based on judgments of an engineering consultant to this project, these are probably reasonable assumptions for the 69kV and the 230kV lines. However, for the 115kV lines, it is more likely that about half are single circuit and half are double circuit. Assuming that all 115 kV lines are double circuit, will underestimate the possible health effects, because it underestimates the number of miles with population exposure. It will also underestimate the cost of (moderate) mitigation, because it is based on a fairly inexpensive reverse or optimal phasing mitigation measures rather than on split phasing.

Another question is how many miles of transmission lines are located on a joint corridor. The statewide analysis assumes that there is no overlap of transmission lines on the same corridor. This results in an overestimate of possible health effects.

Home Grounding Retrofitting

Elevated magnetic fields in homes can also be due to net currents that flow through the water pipe back to the water main. The three contenders among the alternatives that we examined are not to change the grounding system, to improve the net return to the powerline, and to block the return through the water pipe with an insulating coupler.

The simplified models are for a one story home (Home-A) and for a two-story home (Home-B) exposed to elevated fields. Table 3 shows the consequence table imported from the Analytica model base case run of the model Home-A. Figure 18 shows the results for the one-story home. Figure 19 shows the statewide analysis.

Table 3: Data Imported from the Analytica Model Home-A

(Results are for 10 years, fatalities are measured in life years lost, all other estimates are simple counts or dollar values)

Home Grounding - Scenario A: Consequences

Alternatives	Insulate Pipe	Improve Net Return	Do Nothing
Adult Brain Cancer (Fatal)	0.00000	0.00021	0.00053
Adult Brain Cancer (Non-Fatal)	0.00000	0.00001	0.00003
Adult Leukemia (Fatal)	0.00000	0.00027	0.00069
Adult Leukemia (Non-Fatal)	0.00000	0.00002	0.00006
Breast Cancer (Fatal)	0.00000	0.00065	0.00162
Breast Cancer (Non-Fatal)	0.00000	0.00013	0.00034
Alzheimer	0.00000	0.00014	0.00035
Adult Other Health Endpoint (Fatal)	0.00000	0.00000	0.00000
Adult Other Health Endpoint (Non-Fatal)	0.00000	0.00000	0.00000
Childhood Brain Cancer (Fatal)	0.00000	0.00010	0.00025
Childhood Brain Cancer (Non-Fatal)	0.00000	0.00000	0.00001
Childhood Leukemia (Fatal)	0.00000	0.00016	0.00040
Childhood Leukemia (Non-Fatal)	0.00000	0.00001	0.00002
Childhood Other Health Endpoint (Fatal)	0.00000	0.00000	0.00000
Childhood Other Health Endpoint (Non-Fatal)	0.00000	0.00000	0.00000
Cost	$210.00	$168.00	$0.00

OVERALL ANALYSIS:
Home Grounding-Scenario:A
Analytica Model Home-A

CAUTION:
The sliders are set in the middle of the scale, which may not be reasonable For reference, the base case values are in clolumn B.

Total Equivalent Cost per Mile

Alternatives	Do Nothing	Improve Net Return	Insulate Pipe
EMF Health	$13,545.09	$6,772.47	$6,773.90
Cost	$0	$504	$630
Total	**$13,545**	**$7,276**	**$7,404**

USER SELECTIONS

Economic Assumptions	**Base**	**User**	**Min**	**Range**	**Max**
Number of adults in the home	2	2	0		4
Number of children in the home	2	3	0		6
Discount Rate	3%	5.0%	0%		10%
Facts					
Probability of Hazard	0.1	0.5	0		1
Risk Ratio	?	3	1		5
Mitigation Effectiveness					
Improve Net Return	60.00%	50.0%	0%		100%
Insulate Pipe	99.99%	49.99%	0%		100%
Multiplier for Cost	1	3	1		5
Time horizon for Health effects	10	18	1		35
Values					
One Life-Year Lost	$100K	$250,000	$0		$500K
One Non-Fatal Cancer	$300K	$250,000	$0		$500K
One Alzheimers' Case	$200K	$250,000	$0		$500K

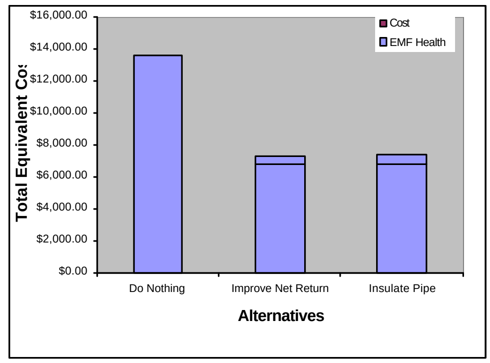


Figure 18: Home Grounding Analysis – Single Story
(Sliders are arbitrarily set in the middle of the scale)

Statewide Analysis
Home Grounding

Caution:
The sliders are arbitrarily set in the middle of the scale. These values may not be reasonable. The base case values of the analysis are shown in the second column.

Total Equivalent Cost per Mile

Alternatives	Do Nothing	nprove Net Retui	Insulate Pipe
EMF Health	$14,029,513,431	$5,553,438,534	$1,402,951
Cost	$0	$168,000,000	$210,000,000
Total Cost	**$14,029,513,431**	**$5,721,438,534**	**$211,402,951**

USERS' SELECTIONS	**Base**	**User**	**Min**	**Range**	**Max**
Number of homes of type A in CA		5000000	0		10M
Number of homes of type B in CA		5000000	0		10M
% homes of type A w/ elevated fields		10.00%	0		20%
% homes of type B w/ elevated fields		10.00%	0		20%
Economic Assumptions					
Number of adults in the home	2	2	0		4
Number of children in the home	2	3	0		6
Discount Rate	3%	5.0%	0%		10%
Facts					
Probability of Hazard	0.1	0.5	0		1
Risk Ratio	2	3	1		5
Time horizon for Health effects	10	18	1		35
Values					
One Life-Year Lost	$100K	$250,000	$0		$500K
One Non-Fatal Cancer	$300K	$250,000	$0		$500K
One Alzheimers' Case	$200K	$250,000	$0		$500K

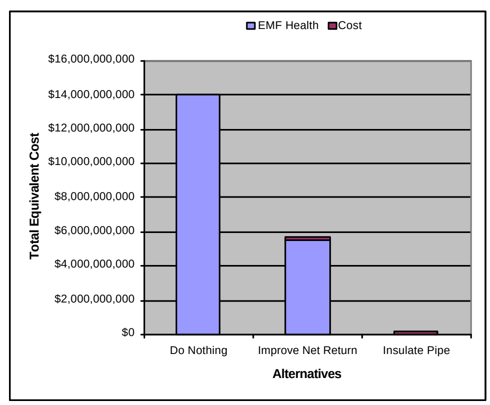


Figure 19: Statewide Analysis of Home Grounding Systems
(Sliders are Set Arbitrarily in the Middle of the Scale)

New Transmission Lines

We also analyzed alternative policies regarding new transmission lines. The conclusions of the final report agreed with current California policy to use inexpensive EMF reduction measures when designing and configuring new lines. The analyses also indicated that increasing the right of way or re-routing new transmission lines is not a cost-effective way of reducing EMF exposure.

To illustrate the results of the new transmission line analyses, Table 4 show the consequence table imported from the Analytica model TN-115 B. Figure 20 shows the EXCEL model for this new transmission line scenario. Since decisions on transmission lines are made on a case-by case basis, there is no equivalent of a statewide analysis.

Table 4: Data Imported from Analytica Model TN-115 B

(Results are for 50 miles and 35 years, fatalities are measured in life years lost, all other estimates are simple counts or dollar values)

New Transmission 115kV - Scenario B: Consequences w/o EMF (no discounting/no financing)

Alternatives	Triangular Post - 50ft ROW	Split-Phase - 50ft ROW	Underground - 50ft ROW
Adult Brain Cancer (Fatal)	8.46	0.53	0.71
Adult Brain Cancer (Non-Fatal)	0.53	0.03	0.04
Adult Leukemia (Fatal)	11.05	0.70	0.92
Adult Leukemia (Non-Fatal)	0.90	0.06	0.08
Breast Cancer (Fatal)	26.04	1.64	2.17
Breast Cancer (Non-Fatal)	5.42	0.34	0.45
Alzheimer	5.63	0.36	0.47
Adult Other Health Endpoint (Fatal)	0.00	0.00	0.00
Adult Other Health Endpoint (Non-Fatal)	0.00	0.00	0.00
Childhood Brain Cancer (Fatal)	1.75	0.11	0.15
Childhood Brain Cancer (Non-Fatal)	0.08	0.01	0.01
Childhood Leukemia (Fatal)	2.76	0.17	0.23
Childhood Leukemia (Non-Fatal)	0.14	0.01	0.01
Childhood Other Health Endpoint (Fatal)	0.00	0.00	0.00
Childhood Other Health Endpoint (Non-Fat	0.00	0.00	0.00
Worker - Brain Cancer (Fatal)	0.00	0.00	0.00
Worker - Brain Cancer (Non-Fatal)	0.00	0.00	0.00
Worker - Leukemia (Fatal)	0.00	0.00	0.00
Worker - Leukemia (Non-Fatal)	0.00	0.00	0.00
Fire Fatalities	0.57	0.57	0.00
Fire Injuries	0.25	0.25	0.00
Collision Fatalities	0.00	0.00	0.00
Collision Injuries	0.00	0.00	0.00
Electrocutions - Public	0.70	0.70	0.13
Construction Fatalities	0.02	0.02	2.77
Construction Injuries	0.11	0.11	14.07
Electrocutions - Workers	0.42	0.42	0.13
TPC	$44,630,000	$45,030,000	$55,710,000
O&M	$661,500	$661,500	$551,300
Conductor Losses	$8,358,000	$6,328,000	$5,640,000
Property Values	$4,575,000	$4,575,000	$0
Property Loss - Fires	$40,500	$40,500	$0
Property Loss - Collisions	$0	$0	$0
Outages - Contingencies	68.22	68.22	63.58
Outages - Customer Interruptions	136400.00	136400.00	127200.00
Aesthetics	0.00	0.00	0.00
Trees	84.00	84.00	0.00
Air Pollution	145500.00	144500.00	125300.00
Noise and Disruption	274.50	274.50	6405.00

OVERALL ANALYSIS:
Distribution Line Retrofit
Analytica Model TN-115-b
(Costs are per Mile)

CAUTION:
The sliders are set in the middle of the scale. These values may not be reasonable. For reference, the analysis base case values are in clolumn B.

Total Equivalent Cost per Mile

Alternatives	**Triang. Post**	**Split Phase**	**Underground**
EMF Health	$6,991,080	$3,574,604	$3,573,155
Cost	$6,135,412	$8,988,816	$11,011,315
Property Values	$653,571	$653,571	$0
Outages	$212,753	$212,753	$198,317
Total	**$13,992,817**	**$13,429,745**	**$14,782,787**
TPC	$5,733,543	$8,677,395	$10,735,458

USER SELECTIONS

Economic Assumptions	**Base**	**User**	**Min**	**Range**	**Max**
% of TPC Financed	80%	50.0%	0%		100%
Interest Rate	10%	10.0%	0%		20%
Discount Rate	3%	5.0%	0%		10%
Facts					
Probability of Hazard	?	0.5	0		1
Risk Ratio	?	3	1		5
Mitigation Effectiveness					
Split Phase - 50 ft. ROW	94%	50.0%	0%		100%
Underground - 50 ft. ROW	92%	50.0%	0%		100%
Total Project Cost Multiplier					
Split Phase (1=4,250K)	1	1.5	0		3
Undergrounding (1=$5,305K)	1	1.5	0		3
Property Values (1=$435K)	1	1.5	0		3
Values					
One Life-Year Lost	$100K	$250,000	$0		$500K
One Non-Fatal Cancer	$300K	$250,000	$0		$500K
One Alzheimers' Case	$200K	$250,000	$0		$500K
One Person-Outage Hour	$10	$10	$0		$20
One Contingency	$10K	$50,000	$0		$100K

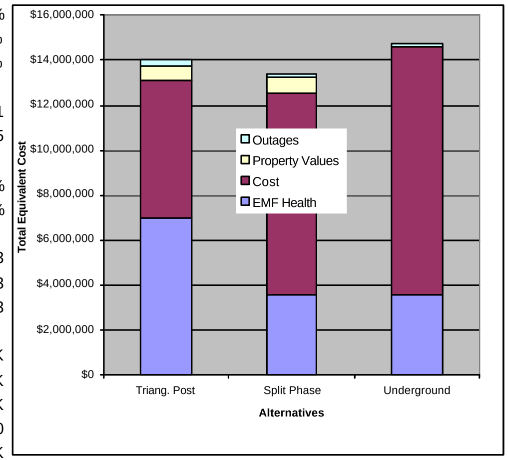


Figure 20: Overall Analysis Sheet of the New Transmisison Line Model TN-115 B

References

von Winterfeldt, D., Adams, J., Eppel, T, and Nair, I. Draft Final Report, Power Grid and Land Use Policy Analysis. Los Angeles: Decision Insights, Inc., 2001a.

von Winterfeldt, D., Adams, J., Eppel, T, and Nair, I. Executive Summary, Power Grid and Land Use Policy Analysis. Los Angeles: Decision Insights, Inc., 2001a.

Appendix A: EXCEL Models

DR-A	Distribution Line Retrofit – Three Wires
DR-B	Distribution Line Retrofit – Four Wires
DR Statewide Base	Statewide Distribution Line Retrofit (Analytica Base Case)
DR Statewide	Statewide Distribution Line Retrofit (Sliders at Mid Point)
TR-69	Transmission Line Retrofit, 69 kV Line
TR-115	Transmission Line Retrofit, 115 kV Line
TR-230	Transmission Line Retrofit, 230 kV Line
TR Statewide Base	Statewide Transmission Line Retrofit (Analytica Base Case)
TR Statewide	Statewide Transmission Line Retrofit (Sliders at Mid Point)
Home-A	Home Grounding Retrofit – One Story
Home-B	Home Grounding Retrofit – Two Stories
Home Statewide Base	Home Grounding Retrofit (Analytica Base Case)
Home Statewide	Home Grounding Retrofit (Sliders at Mid Point)
TN-115B	New Transmission Lines